Intersecting inequities in energy consumption, decent living standards and risk of climate change exposure in Ghana, India, and Brazil

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Highlights

- We combine consumer expenditure microdata over two time periods from Brazil (2002/2017), Ghana (2005/2017) and India (2004/2011) with a spatial climate exposure dataset (SSP2, 1.5dC, 2030)
- We show that poorer households face either limited access to clean energy sources or unaffordable supply once this improves.
- We show that the same households are likely deprived of multiple dimensions of Decent Living Standards (DLS), highlighting heterogeneity across these.
- Our work then identifies intersecting inequities, both geographically and by income level, of climate change risk, DLS deprivation and energy unaffordability.

Extended Abstract

Energy services are important for decent living and reducing vulnerabilities to climate change but demands far beyond decent living needs have implications for climate mitigation efforts (O'Neill et al., 2018; Oswald et al., 2020; Wiedmann et al., 2020). Literature linking residential energy consumption with human development and poverty alleviation is growing but has been largely concentrated at the aggregate level (Rao et al., 2019; Millward-Hopkins et al., 2020; Kikstra et al., 2021). Efforts to disaggregate patterns of residential energy consumption linked with wellbeing are starting to emerge and motivate further development of methods and application across other regions (Baltruszewicz et al., 2021; Oswald et al., 2021). This has relevance across a range of fields of study, from improving on indicators of absolute poverty, to modelling energy needs for decent living conditions and identifying vulnerable populations at acute risk of escalating anthropogenic climate change.

In this work, we combine consumer expenditure microdata for two time periods from Brazil (2002/2017), Ghana (2005/2017) and India (2004/2011) with a spatial climate exposure dataset (SSP2, 1.5dC, 2030) to identify intersecting inequities by income and location.

We begin our analysis by describing household residential and private mobility fuel consumption, identifying consistent shifts towards clean household fuels and even sharper shifts to private mobility fossil fuel consumption among the upper deciles (Figure 1). This energy consumption data provides important context across our study regions[1]. In India and Ghana, across both time periods, clean household fuel consumption begins to replace traditional household fuels among the upper deciles in the later survey year, while traditional fuels continue to dominate among the lower deciles. In Brazil, we see an increase in clean household fuel consumption across all deciles, though it should be noted that other aggregate data sources provide evidence that firewood consumption most certainly persists in rural areas and for lower-income households; albeit at much lower levels than the other two countries. Notably, average fossil fuel consumption for private mobility rose dramatically among the wealthiest decile in Ghana and India and remains almost twice as high among the wealthiest decile relative to the next wealthiest decile in Brazil.

[1] Note that collected biomass (distinct from purchased biomass) was able to be imputed for both survey years in India and Ghana, but not able to be included in final energy consumption in the latter survey year for Brazil.

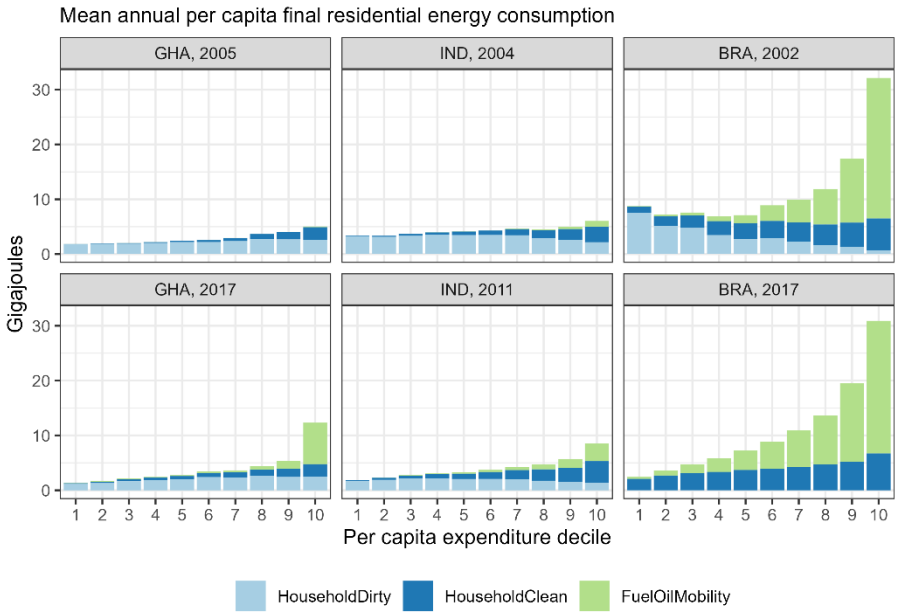

Figure 1 - Mean annual per capita residential energy consumption.

We take a closer look at clean fuel consumption and affordability trends in Figure 2. Here, the dual challenge of energy access and affordability among poorer households is evident. In India and Ghana, clean fuel consumption remains at very low levels, not exceeding 1 Gigajoule (GJ) per capita for the bottom five deciles. This is due to issues of poor access to modern fuels among poorer populations and the inability to purchase requisite appliances for basic household energy services. In contrast, poorer households in Brazil generally have access to clean fuels and necessary appliances by 2017, facing instead issues of fuel affordability, where a nominal consumption of 2 GJ per capita reflects on average approximately 17% of the household budget for the lowest decile in 2017. This is far beyond the rudimentary 10% budget threshold defining fuel poverty in developed regions; indeed, the bottom three deciles in Brazil are at or above this threshold in 2017.

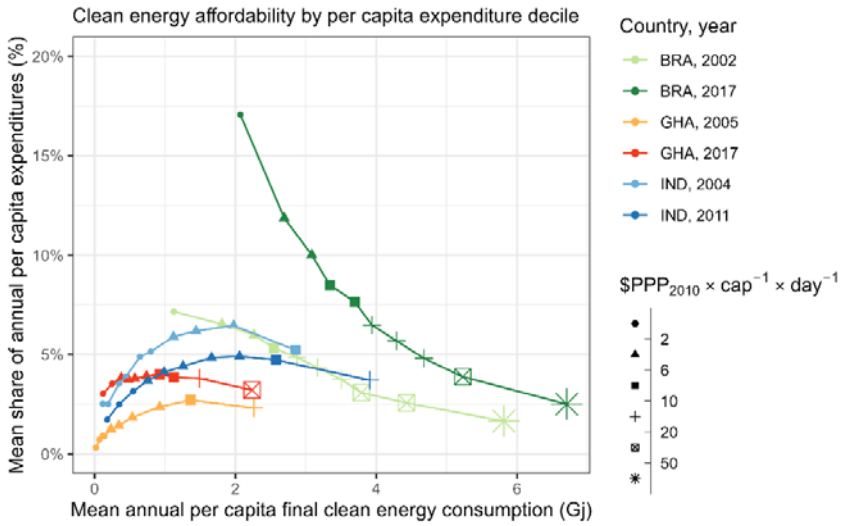

Figure 2 - Clean energy consumption and affordability

Moving on from inequities in household energy consumption, we consider household access to the decent living standards (DLS), a multi-dimensional framework of energy and material requirements for human wellbeing (Rao & Min, 2018). The DLS represent an important methodological advancement in capturing heterogeneity in material requirements for human wellbeing at the lower income deciles. Similar advances are evident in the demographic literature with respect to measuring years of good life (YoGL) which encompass elements of income poverty and health and

educational dimensions of DLS (Lutz et al., 2021). We operationalize the DLS using a set of heuristics that reflect our attempt to capture the intention of the original framework in quantitative terms (see Table 1). Our set of heuristics is evidently not complete, as data limitations prevent us from drawing conclusions on access to decent clothing, nutrition, and roads.

Table 1 - Heuristics for determining household access to Decent Living Standards.

Needs group	Dimension	Heuristic
Shelter	Housing	Solid construction housing, and maximum 2 persons per room
Shelter	Thermal comfort	Access to thermal comfort devices (fans or space heaters, as required)
Shelter	Clothing	*not covered*
Nutrition	Preparation	Access to clean cookstoves
Nutrition	Nutrients	*not covered*
Nutrition	Storage	Access to a fridge or a freezer
Health & Hygiene	Water	Piped water connection into at least one room
Health & Hygiene	Sanitation	Permanent flush toilet or similar in the home
Health & Hygiene	Healthcare	All household members over the age of 16 have health insurance
Socialization	Education (Basic)	All household adults have completed at least 6 years of education
Socialization	Education (Senior)	All household adults have completed at least 12 years of education
Socialization	Connectedness	Access to either a phone, smart-phone, or computer
Mobility	Roads	*not covered*
Mobility	Connectedness	Access to a motorbike/scooter, car, or public transport

Figure 3 describes disaggregate access to each dimension of the DLS across population deciles. We find evidence of heterogenous starting points and improvement trends across distinct dimensions in each country. It would appear that health and education are the slowest to improve, even among wealthier deciles, although the effects of progressive healthcare policy are clearly evident in Ghana.

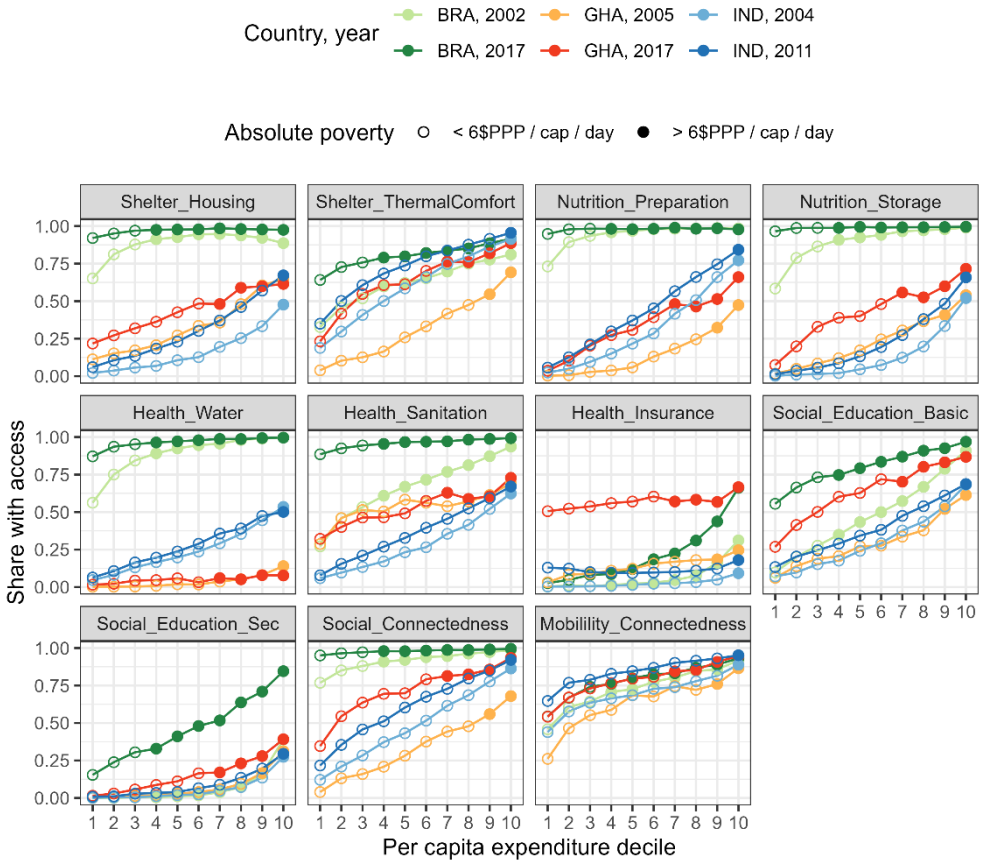

Figure 3 - Access to distinct dimensions of the Decent Living Standards.

Connecting these two strands of analysis, we link DLS deprivation (the inverse of achievement in Fig. 3) in the latest available survey year with estimated climate change exposure risk in 2030. We do this both by income level and geographically to identify the acutely vulnerable population requiring urgent climate adaptation policy support in each country. Table 2 lists the individual indicators aggregated to arrive at climate change exposure through the water-land-energy sectors. We follow the method laid out in the original publication for this aggregation process (Byers et al., 2018)[2].

Table 2 - Climate change exposure sectors and corresponding indicators, modified from Table 1 in Byers et al (2018)

Sector	Indicator
Water	Water stress index Non-renewable groundwater stress index Drought intensity Peak flows risk Seasonality Inter-annual variability
Energy[2]	Heat event exposure Cooling demand Hydroclimate risk to power production
Food and environment (land)	Crop yield change Agricultural water stress index Habitat degradation Nitrogen leaching

We first show the share of population in each decile at risk of climate change exposure through the water-land-energy sectors (y-axis) against the average decile DLS deprivation (x-axis), in Figure 4. We focus our attention on the poorer deciles (with average incomes below 6PPP_{2010}$ per capita – shown as triangles and circles). For the water sector we observe that India has the largest population both severely deprived of DLS and at risk of exposure, reflecting almost half of the population in the bottom five deciles. The downward sloping trends here are due to higher income households being located predominately in urban areas and those urban areas being generally more water stressed. For the energy sector we find extreme levels of risk across the entire population in Ghana and higher levels of risk in India and Brazil. Here the climate exposure risks remain consistent or increase among poorer populations deprived of DLS. For the land (food) sector, we observe the similar levels of climate exposure risk across all three countries, however trends diverge by decile. Here India follows a different pattern with lower income deciles being exposed more strongly while in Brazil and Ghana this is reversed. This is again likely due to patterns of human geography and urban-rural differences.

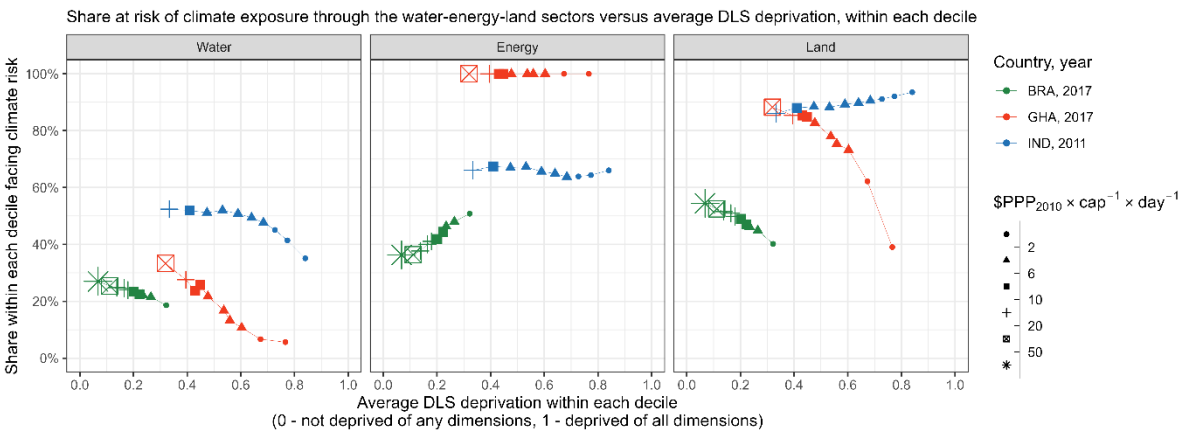

Figure 4 - Share of each decile at risk of climate change exposure in 2030 versus average decile DLS deprivation

[2] Note that we remove 'clean cooking' as one of the indicators originally used in defining risk of climate exposure through the energy sector as this is included in the Decent Living Standards framework.

We then consider geographic distribution and intersections of inequities in DLS deprivations and climate exposure in Figure 5. In Ghana (first row), deprivation levels are high throughout the country and intersect with water sector and land sector exposure in more urban regions and in the south. Energy sector exposure on the other hand is evident across the entire country as expected given the earlier analysis. The picture in India (middle row) is somewhat similar in that deprivation is evident across the entire country, however the intersection with climate exposure risk patterns is unique across sectors. This deserves further analysis and is likely related with the low levels of urbanization relative to the other two countries and corresponding large poorer rural population in the country. Finally, we see in Brazil (last row) generally lower levels of deprivation and again unique patterns of intersecting exposure. Here, energy and land sectors represent the largest risk of climate exposure to the country's poorer populations, though evidence of urban water stress remains.

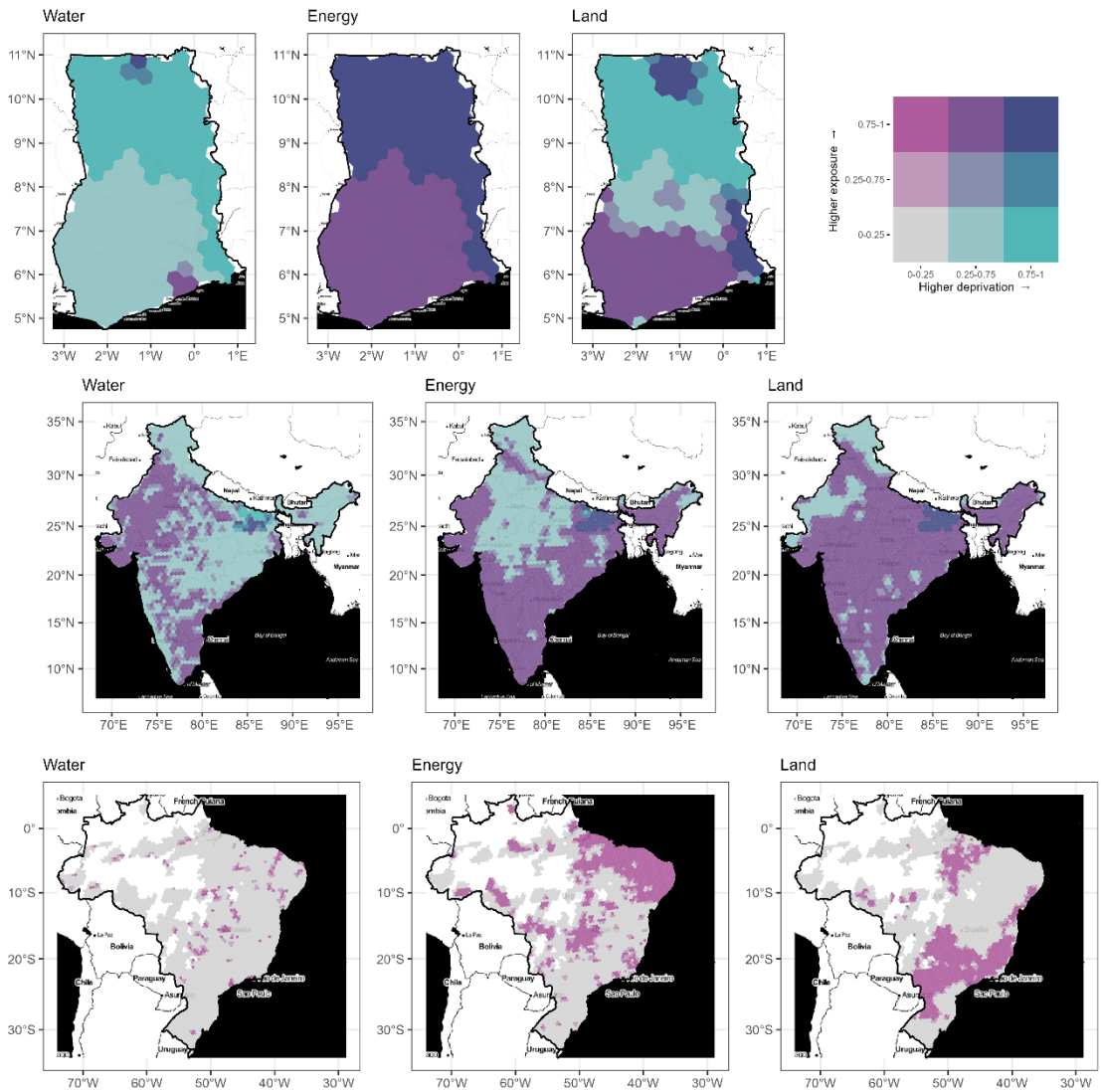

Figure 5 - Intersecting risk of climate exposure in 2030 and DLS deprivation in the latest survey year.

We conclude this extended abstract by reiterating that our work serves to identify particularly vulnerable populations lacking access to decent living standards and likely to face significant climate risks in the near term. These same populations also currently face limited access to clean fuels or issues with affordable access once this improves. Subsequent discussion of our findings will reflect on the nature and targeting of interventions necessary to accelerate the provision of DLS and enable resilient development. In broad terms, focus must be put on improving provisioning for decent living standards to enhance the adaptive capacities of populations particularly vulnerable to climate risks.

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